

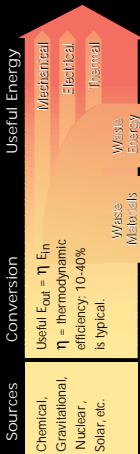
Fusion reactions power the sun and other stars in fusion reactions, four mass nuclei combine, or fuse, to form more massive nuclei. The fusion process converts mass (m) into kinetic energy (E_k), as described by Einstein's formula, $E = mc^2$. In the sun, a sequence of fusion reactions named the P-P chain begins with protons, the nuclei of ordinary hydrogen, and ends with alpha particles, the nuclei of helium atoms. The P-P chain provides most of the sun's energy, and it will continue to do so for billions of years.

Fusion

ENERGY SOURCES & CONVERSIONS

AN OVERVIEW OF ENERGY CONVERSION PROCESSES

Energy can take many forms, and various processes convert one form into another. While total energy always remains the same, most conversion processes reduce useful energy.



HOW FUSION REACTIONS WORK

NUCLEAR PHYSICS OF FUSION

Fusion of low-mass elements releases energy, as does fission of high-mass elements.



Nuclear Reaction Energy: $\Delta E = \kappa (m_i - m_f) c^2$

From Einstein's $E = m c^2$, $\Delta E = \text{energy change per reaction}$, $m_i = \text{total initial (reactant) mass}$, $m_f = \text{total final (product) mass}$. The conversion factor κ is $1 \text{ g in SI units, or } 9.31466 \text{ MeV}/c^2$, when E is in MeV and m is in atomic mass units, u.

Useful Nuclear Masses

(The electron mass is 0.000549 u)

Label Species Mass (u)

n ($1n$) neutron 1.008665

p ($1H$) proton 1.007276

D ($2H$) deuterion 2.013553

T ($3H$) triton 3.015500

3He helium-3 3.014932

α ($4He$) helium-4 4.001505

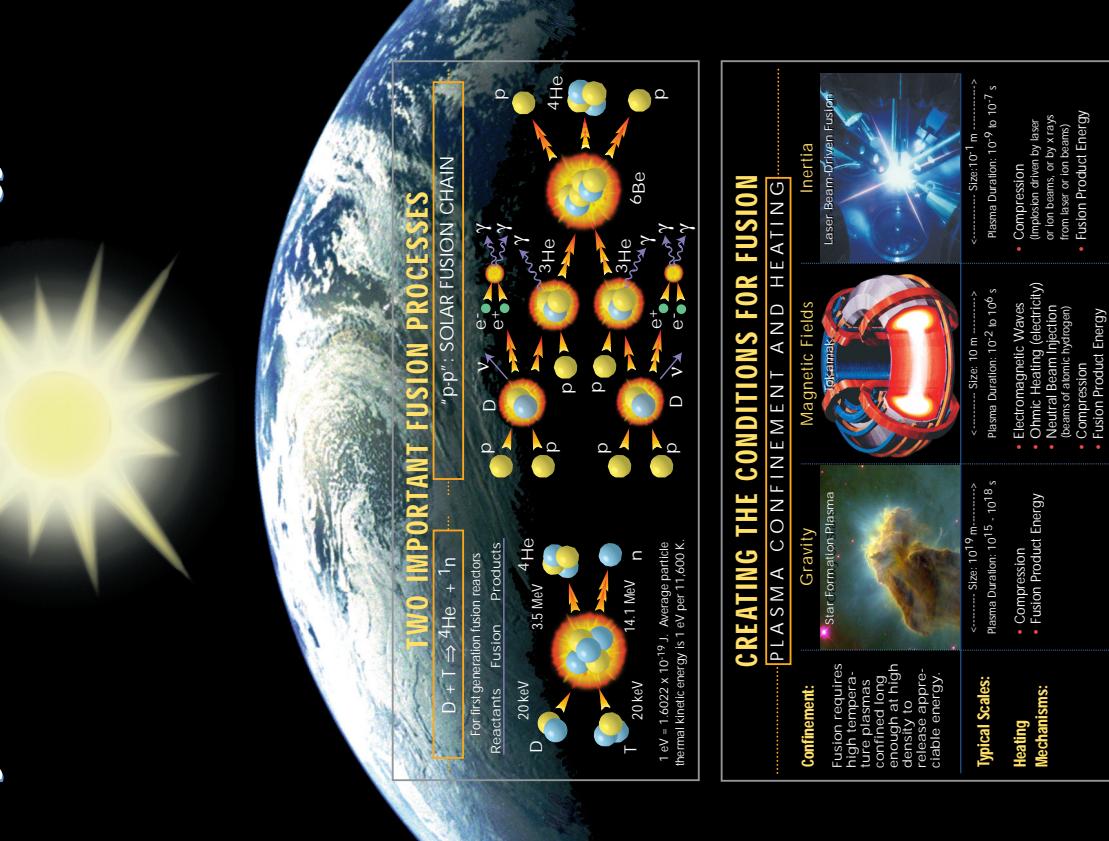
$R = 1.60054 \cdot 10^{-27} \text{ kg} \cdot 9.31466 \text{ MeV}/c^2$

Plasma Fusion Reaction Rate Density = $R n_1 n_2$

$n_1, n_2 = \text{densities of reacting species (ions/m}^3\text{)}$

Multiply by ΔE to get the fusion power density

Physics of a Fundamental Energy Source

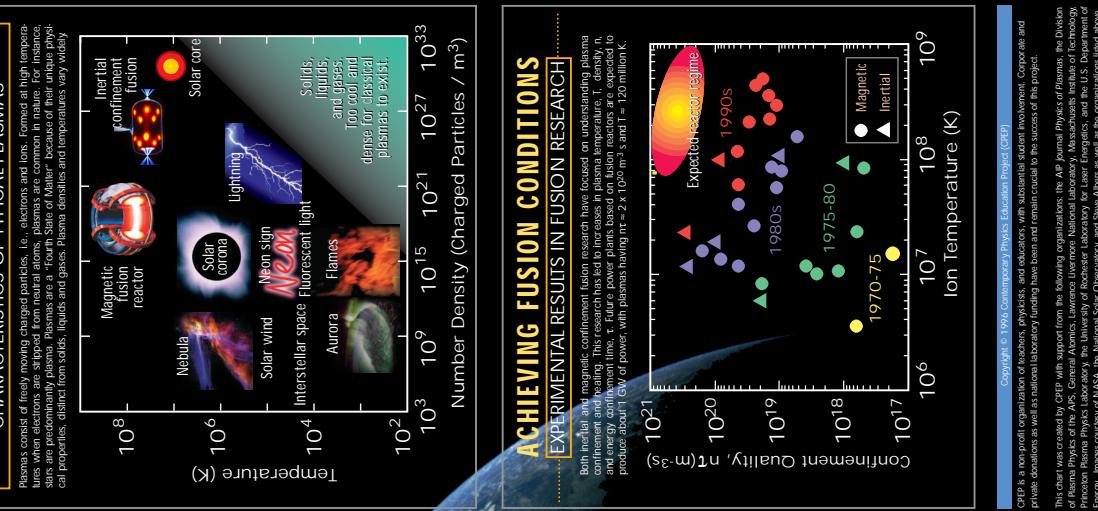


To make fusion

fusion happen on the earth, atoms must be heated to very high temperatures, typically above 10^{10} million K. In this high temperature state, the atoms are ionized. For net energy gain, plasma must be held together (confined) long enough that many fusion reactions occur. If fusion becomes practical, they would provide a virtually infinite energy supply because of the abundance of fuels like deuterium.

PLASMAS – THE 4th STATE OF MATTER

CHARACTERISTICS OF TYPICAL PLASMAS



CPB is a non-profit organization of teachers, physicists, and educators, with substantial student involvement. Corporate and private donations as well as national laboratory funding have been and remain crucial to the success of the project.

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Images courtesy of NASA, the National Solar Observatory, and Steve Allen as well as the organizations listed above.